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D KLEPPNER APR 88 N00014-79-C-0183

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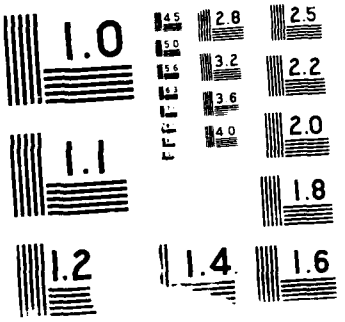
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FINAL REPORT

Infrared Detection Using Rydberg Atoms

Office of Naval Research
Contract N00014-79-C-0183

covering the period
1 March 1979 - 30 November 1987

Submitted by
Daniel Kleppner

April 1988

Massachusetts Institute of Technology
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Cambridge, Massachusetts 02139

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Work by D. Kleppner and his collaborators is summarized here.

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ONR Contract N000 14-79-C-0183
RYDBERG ATOMS AND RADIATION
03/01/79 - 11/30/87

Principal Investigator:
Daniel Kleppner
Research Laboratory of Electronics and Department of Physics
Massachusetts Institute of Technology

PRINCIPAL ACHIEVEMENTS

This is the final report on a program of research on Rydberg Atoms and Radiation supported by the Office of Naval Research between March, 1979 and November, 1987. The goal of the program was to use Rydberg atoms to explore new types of fundamental radiative phenomena. As demonstrated by the research generated by this line of inquiry in laboratories in the U.S. and abroad, the program has been successful. A new area of study that has been come to be called "Cavity Quantum Electrodynamics" has emerged in the last few years. Research under this grant on inhibited spontaneous emission is often regarded as seminal in that development. The Principal Investigator was awarded the 1986 Davisson-Germer Prize of the American Physical Society for research on Rydberg Atoms in applied fields: research under this grant was central to that achievement.

Early work under the grant involved developing techniques for studying radiative transfer of Rydberg atoms on a level-by level basis [1-3]. (References are to the list of publications below.) During this time the P.I. conceived the idea of "turning off" spontaneous emission by Rydberg atoms [4,5]. A closely related idea— the inhibition of black-body radiative transfer— was demonstrated shortly thereafter [6]. Full demonstration of inhibited spontaneous emission required the development of a technique for transferring atoms to the so-called "circular" Rydberg states. These are states of the highest possible angular momentum for a given principal quantum number. Success in this was reported in [8]. Our method has been adapted in other laboratories, and is now being employed in Rydberg atom studies and in a new type of measurement of the Rydberg constant. The most exciting advance

under the grant has been the demonstration that spontaneous emission can indeed be "switched off" [9], an experiment that has attracted wide attention.

The final phase of research under this grant has been the study of spontaneous atom-cavity oscillations induced by the vacuum field, a phenomenon that can be loosely described as "reversible" spontaneous emission. Unfortunately, the technical obstacles turned out to be more formidable than anticipated, and we have not yet achieved that goal. The research is being carried forward under sponsorship of the Joint Services Electronics Program at MIT, and we are hopeful that it will be brought to a successful conclusion. Publications of that work will carry full acknowledgement of the ONR sponsorship of the research.

DEGREES GRANTED

Ph.D. William P. Spencer, 1982: "Radiative Processes Among Rydberg Atoms".

Ph.D. A. Ganesh Vaidyanathan, 1982: "Far Infrared and Microwave Studies of Rydberg Atoms".

Ph.D. Randall G. Hulet, 1984: "High Angular Momentum Rydberg States: The Production and Study

Bachelor of Science, Subir Sachdev, 1982: "Quantum Electrodynamics in a Damped Cavity" (Winner of 1982 APS Apker Prize.)

Two additional Ph.D. degrees are expected to be awarded in the coming year.

PUBLICATIONS UNDER THE GRANT

1) Temperature Dependence of Blackbody-Radiation-Induced Transfer Among Highly Excited States of Sodium, William P. Spencer, A. Ganesh Vaidyanathan, Daniel Kleppner and Theodore W. Ducas, Phys. Rev. A, 25 380 (1982).

2) Measurements of Lifetimes of Sodium Rydberg States in a Cooled Environment, William P. Spencer, A. Ganesh Vaidyanathan, Daniel Kleppner and Theodore W. Ducas, Phys. Rev. A, 24 2513 (1981).

3) Photoionization by Blackbody Radiation, William P. Spencer, A. Ganesh Vaidyanathan, Daniel Kleppner and Theodore W. Ducas, Phys. Rev. A, 26, 1490 (1982).

4) Turning Off the Vacuum, Daniel Kleppner, *Laser Spectroscopy V*, ed. A.R.W. McKellar, T. Oka and B.P. Stoicheff, (Springer-Verlag, 1981) p. 292.

5) Inhibited Spontaneous Emission, D. Kleppner, Phys. Rev. Lett., 47, 233 (1981).

6) Inhibited Absorption of Blackbody Radiation, A. Ganesh Vaidyanathan, William P. Spencer, and Daniel Kleppner, Phys. Rev. Lett., 47, 1592 (1981).

7) Atoms in Very Strong Fields, D. Kleppner, *Laser-Plasma Interactions*, Les Houches, Session XXXIV, R. Balian and J.C. Adam (eds.), North-Holland, 1982, p. 734.

8) Rydberg Atoms in "Circular" States, R.G. Hulet and D. Kleppner, Phys. Rev. Lett. 51, 1430 (1983). Experimental Study of Nonadiabatic Core Interactions in Rydberg States of Calcium, A.G. Vaidyanathan, W.P. Spencer, J.R. Rubbmark, H. Kuiper, C. Fabre and D. Kleppner, Phys. Rev. A, 26 3346 (1982).

9) Inhibited Spontaneous Emission by a Rydberg Atom, R.G. Hulet, E.S. Hilfer and D. Kleppner, Phys. Rev. Lett., 55, 2137 (1985).

10) An Introduction to Cavity Quantum Electrodynamics, Daniel Kleppner, Proceedings of the OJI International Seminar on Highly Excited States of Atoms and Molecules, (Fuji-Yoshida, Japan, 1986), S.S. Kano and M. Matsuzawa, eds.

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